Extraction of the F_2 and F_L structure functions from inclusive e+p and e+A at eRHIC

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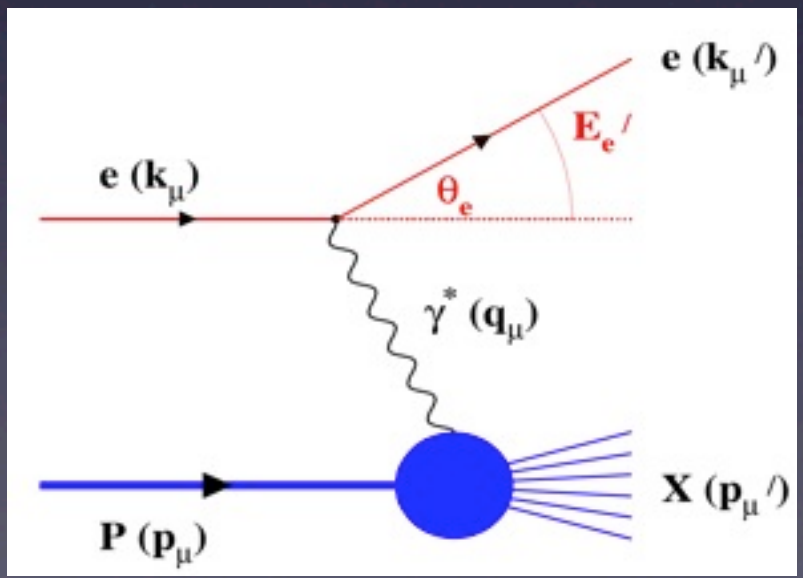
The neutral current inclusive e-nucleon cross section can be written as a combination of two terms:

$$\sigma_r(x,Q^2,y) = \frac{d^2\sigma}{dxdQ^2}\cdot\frac{Q^4x}{2\pi\alpha^2Y_+} = F_2(x,Q^2) - \frac{y^2}{Y_+}\cdot F_L(x,Q^2)\ ,$$

"reduced cross section"

$F_2 \alpha (\sigma_T + \sigma_L)$ $F_L \sim \sigma_L$ where σ_T and σ_L are the γ^*P cross sections for transverse and longitudinally polarized virtual photons. The value of F_2 is determined by the sum of quark and anti-quark distributions, whereas F_L depends on quark + gluon distributions. Above some value of $Q^{2,}$ quark PDFs are much smaller than gluon PDFs hence F_L is mainly "driven" by gluon PDFs

$e(k) + p(p) \rightarrow e(k') + X$



$$Q^2 = -q^2 = -(k_\mu - k_\mu^{'})^2$$

$$Q^2 = 4E_eE_e^{'}sin^2(\frac{\theta_e^{'}}{2})$$

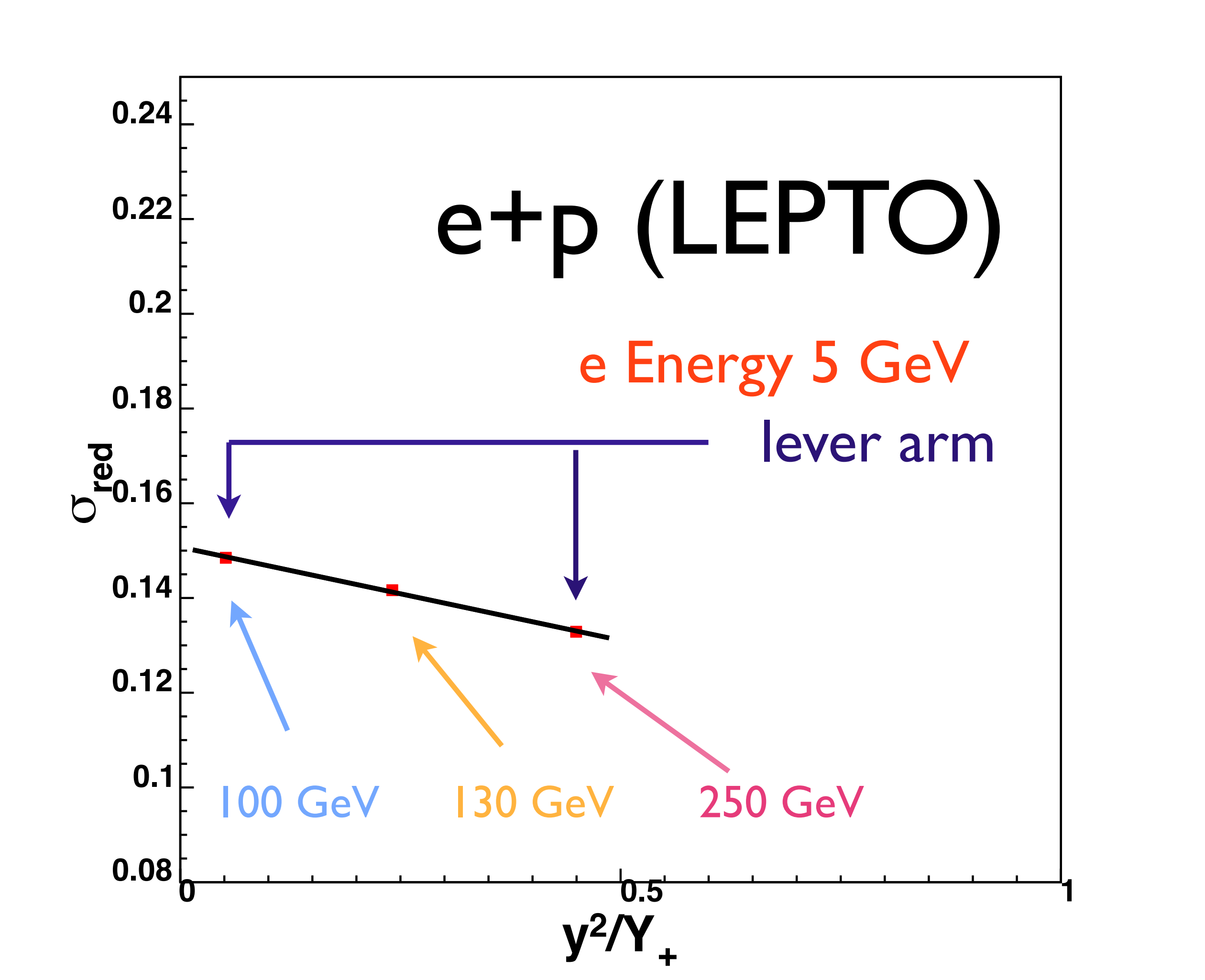
Measure of resolution power or "Virtuality"

$$y = \frac{pq}{pk} = 1 - \frac{E_{e'}}{E_e}cos^2(\frac{\theta_e^{'}}{2})$$

Measure of inelasticity

$$x = \frac{Q^2}{2pq} = \frac{Q^2}{sy}$$

Measure of momentum fraction of struck quark

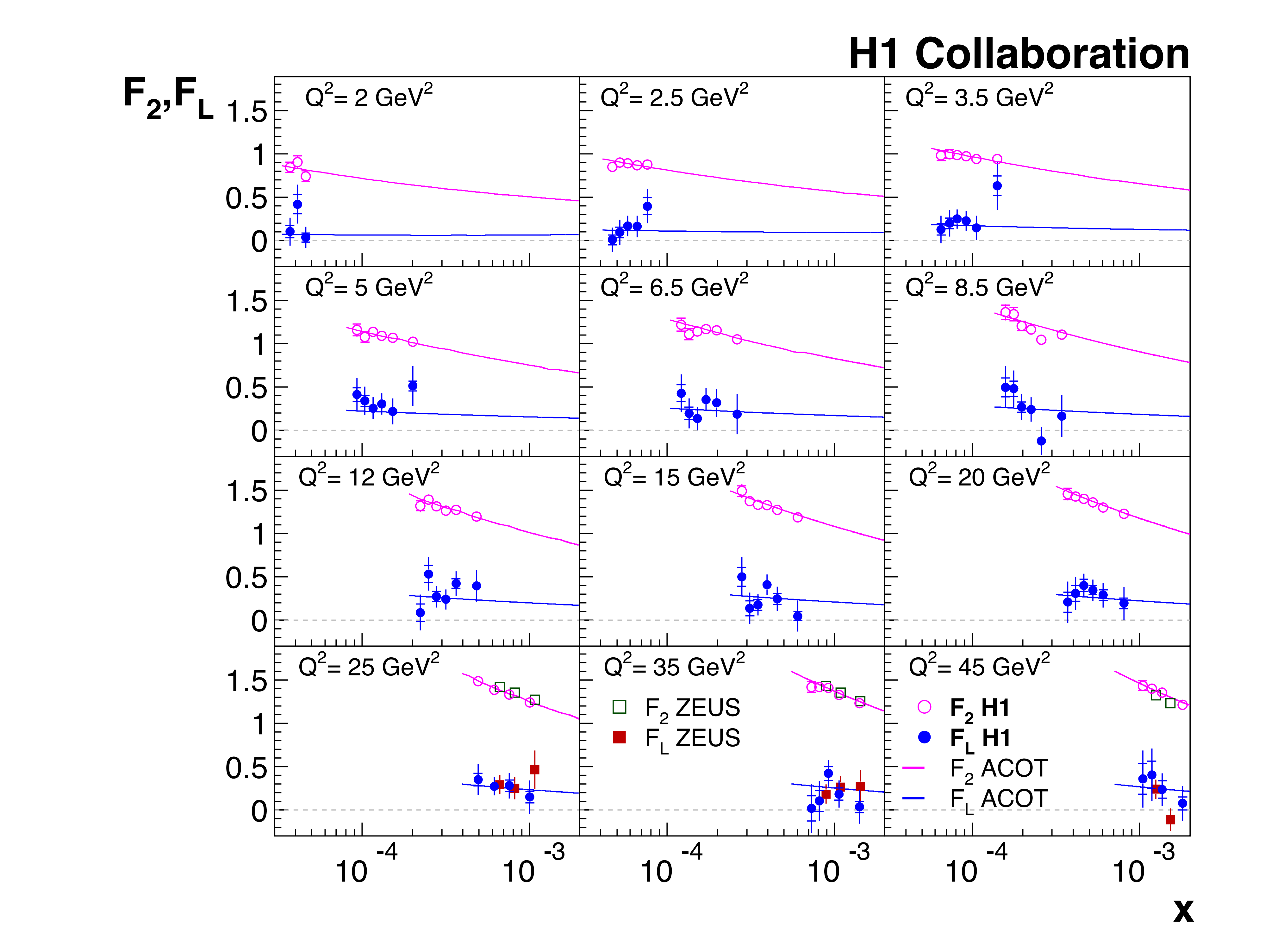


Proton energies selected to make the three points equidistant

For a particular value of electron energy, at fixed values of x and Q^2 one measures 3 values of σ_{red} by changing the hadron beam energy → three values of y^2/Y_+ where $Y_+ = 1+(1-y)^2$

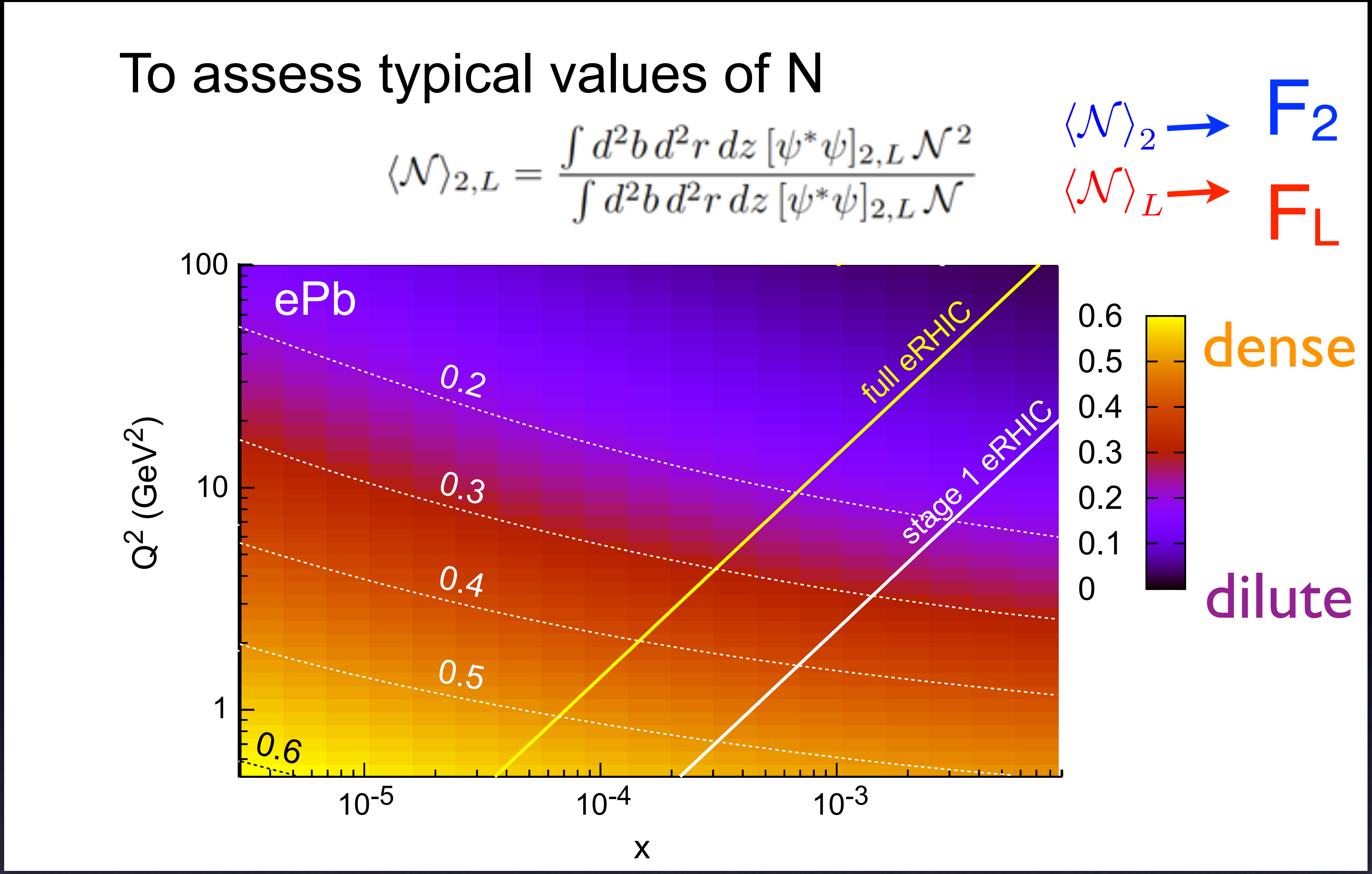
The three measurements line up and can be fit to straight lines, F_2 being the intercept and F_L the slope.

Data is binned in Q^2 and y. The y binning for data with lowest proton energy translates x binning. Other data sets are binned following the relation: $y_2 s_2 = y_1 s_1$. This scaling fixes the value of x for the three corresponding y bins.



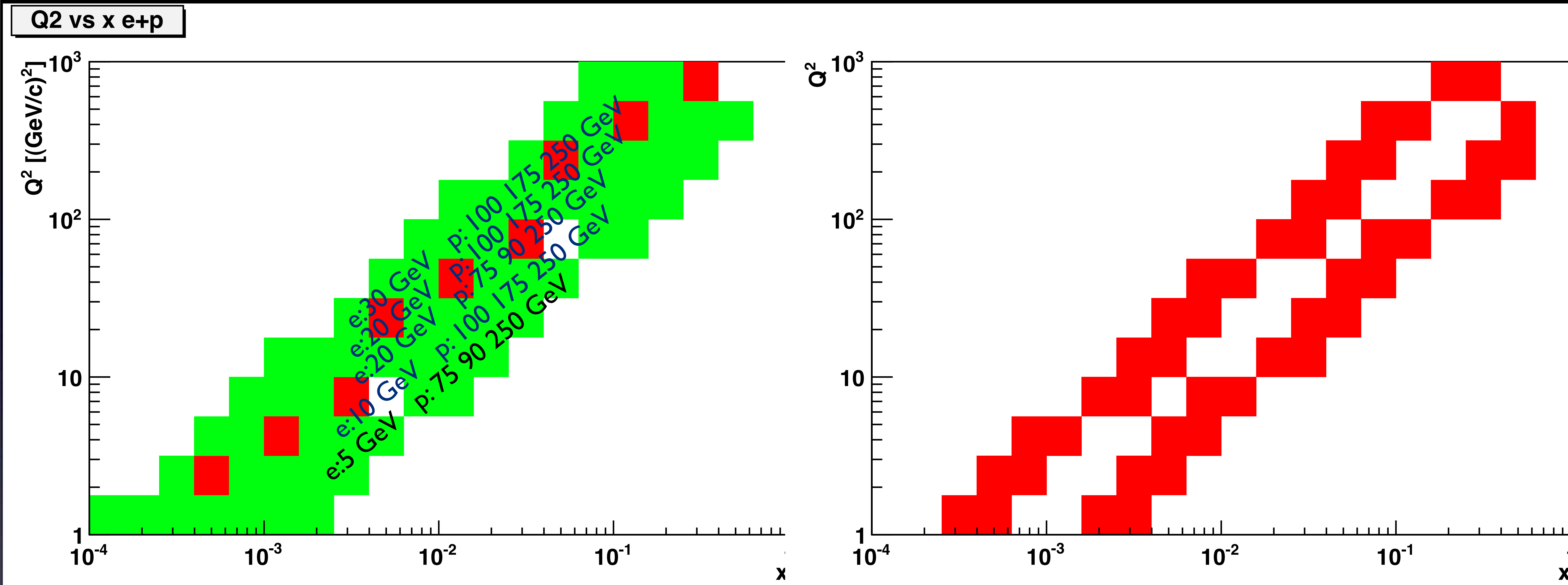
The H1 collaboration has extracted F_L in e+p collisions at HERA. Their measurement reached values of x below 10^{-4} at Q^2 GeV/c^2

F_L extracted from e+A collisions will explore the onset of saturation;



As function of x one explores the behavior of the extracted F_L as Q^2 decreases. A taming of the PDF growth is expected if saturation is present.

Kinematic coverage for FL extraction in ep and eA collisions



The basic conditions the define this ranges are:

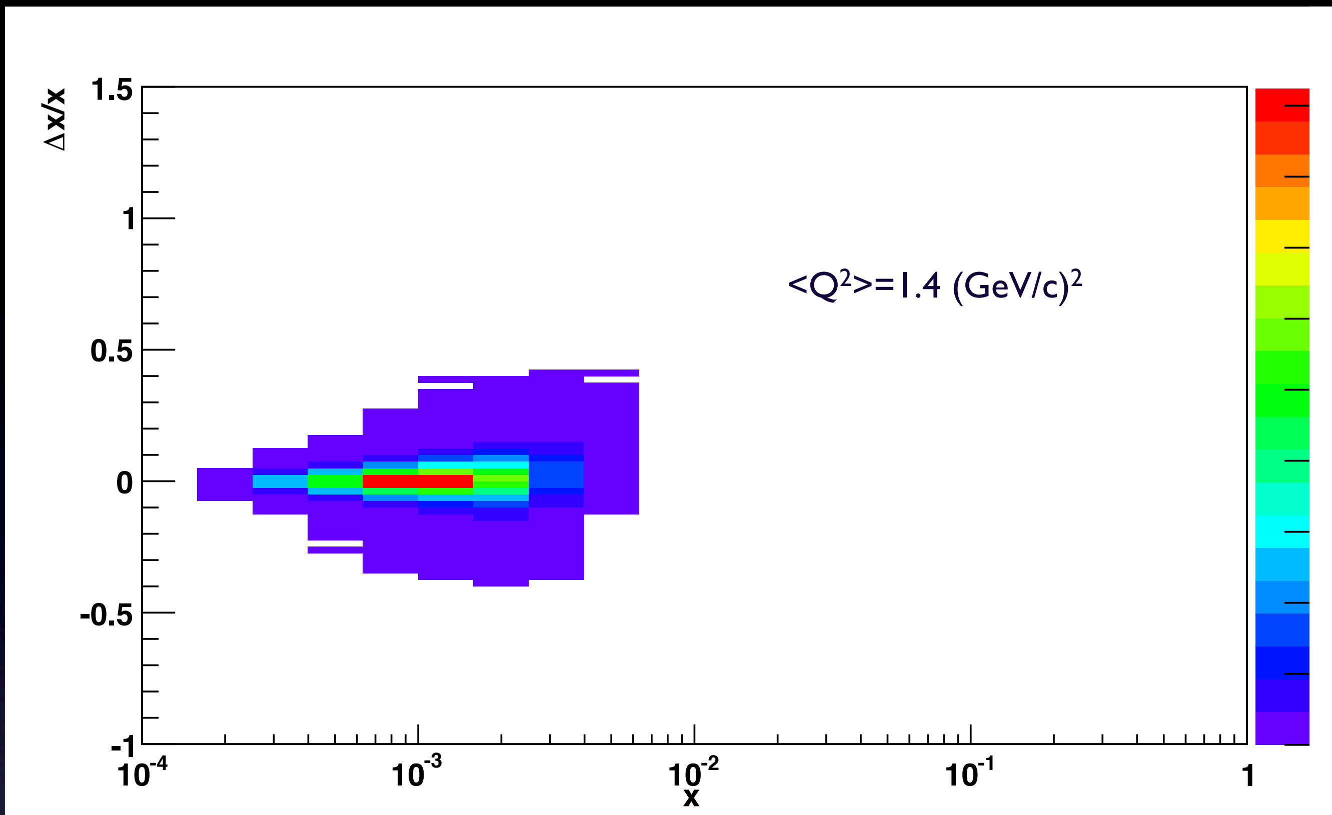
0.01< y<0.9,

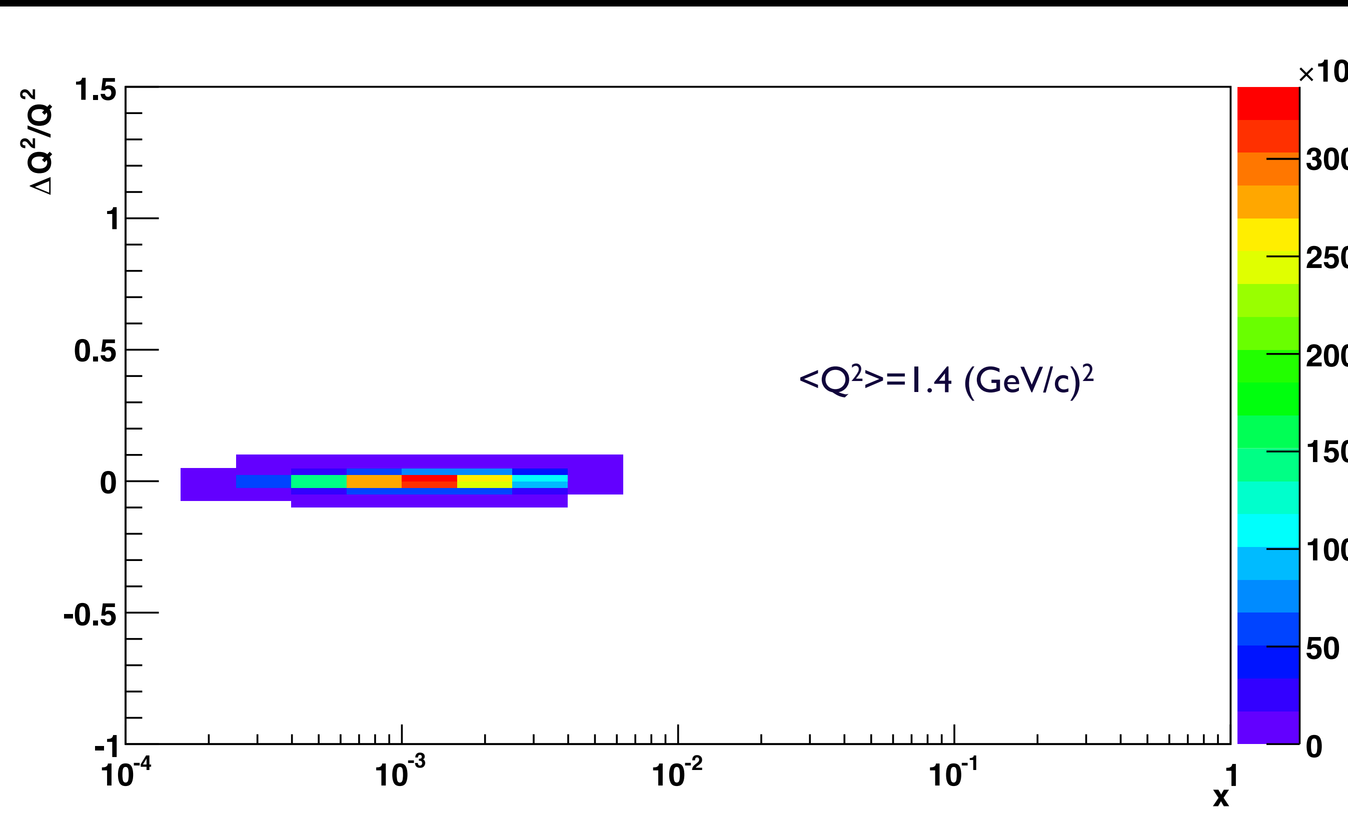
lever arm in y^2/Y_+ >0.1

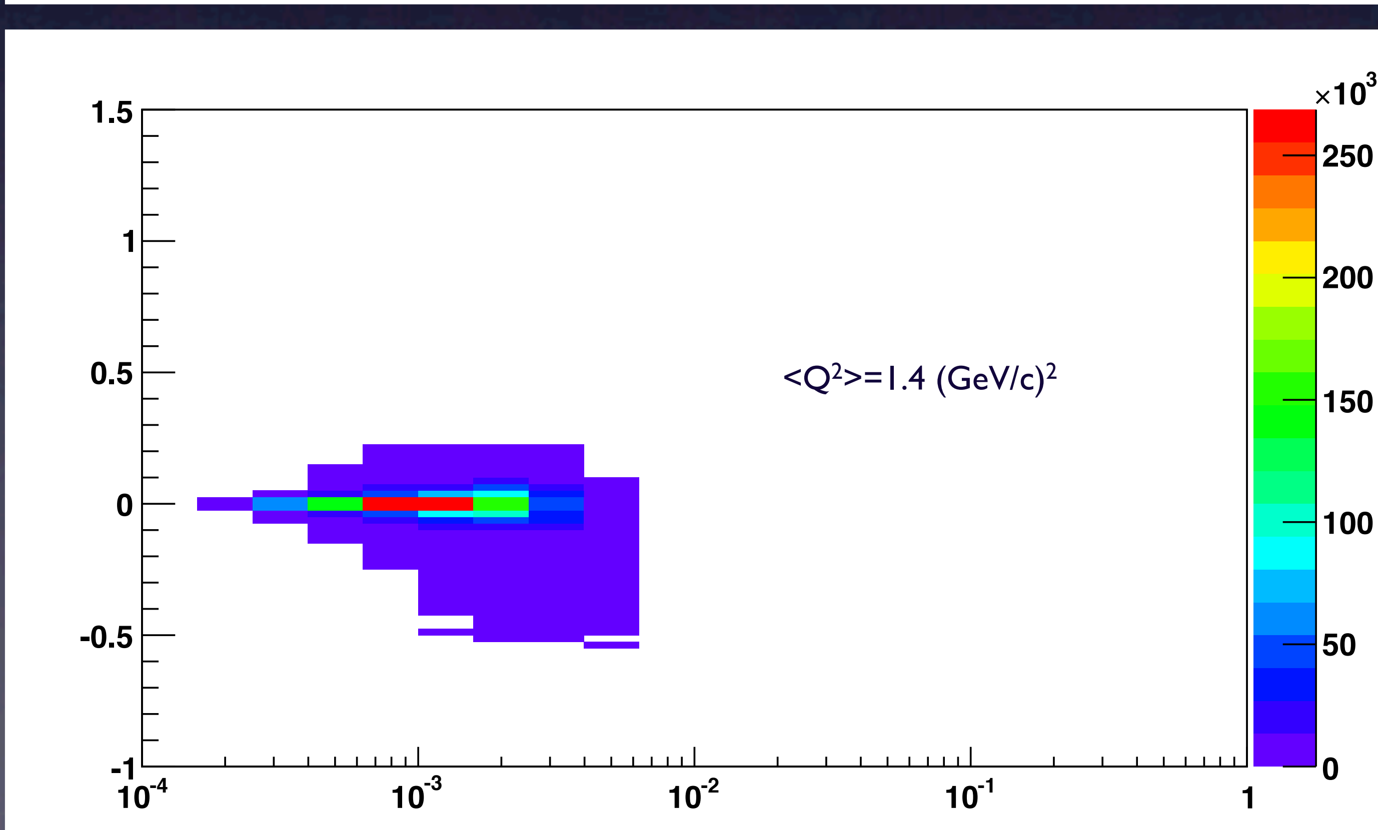
electron scattering angle: 0.5<θ<179.5 degrees.

electron momentum p>500 MeV/c

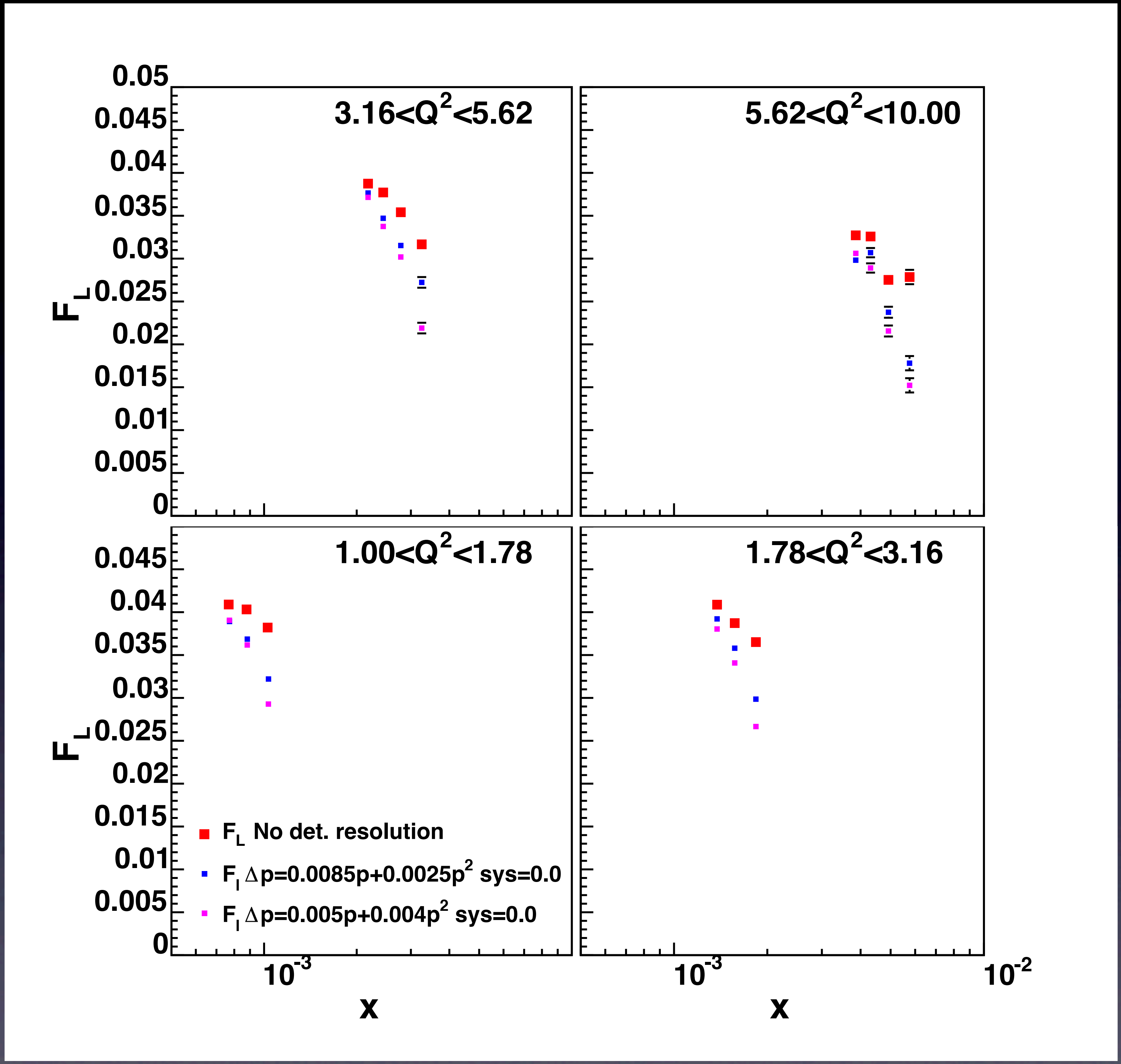
Detector resolution effect on kinematic variables







Compounded effect of:
p resolution:
$\Delta p = 0.0085p + 0.0025p^2$ [GeV/c]
e scattering angle:
$\Delta\theta = 0.0005 + 0.003/p$ [radians]



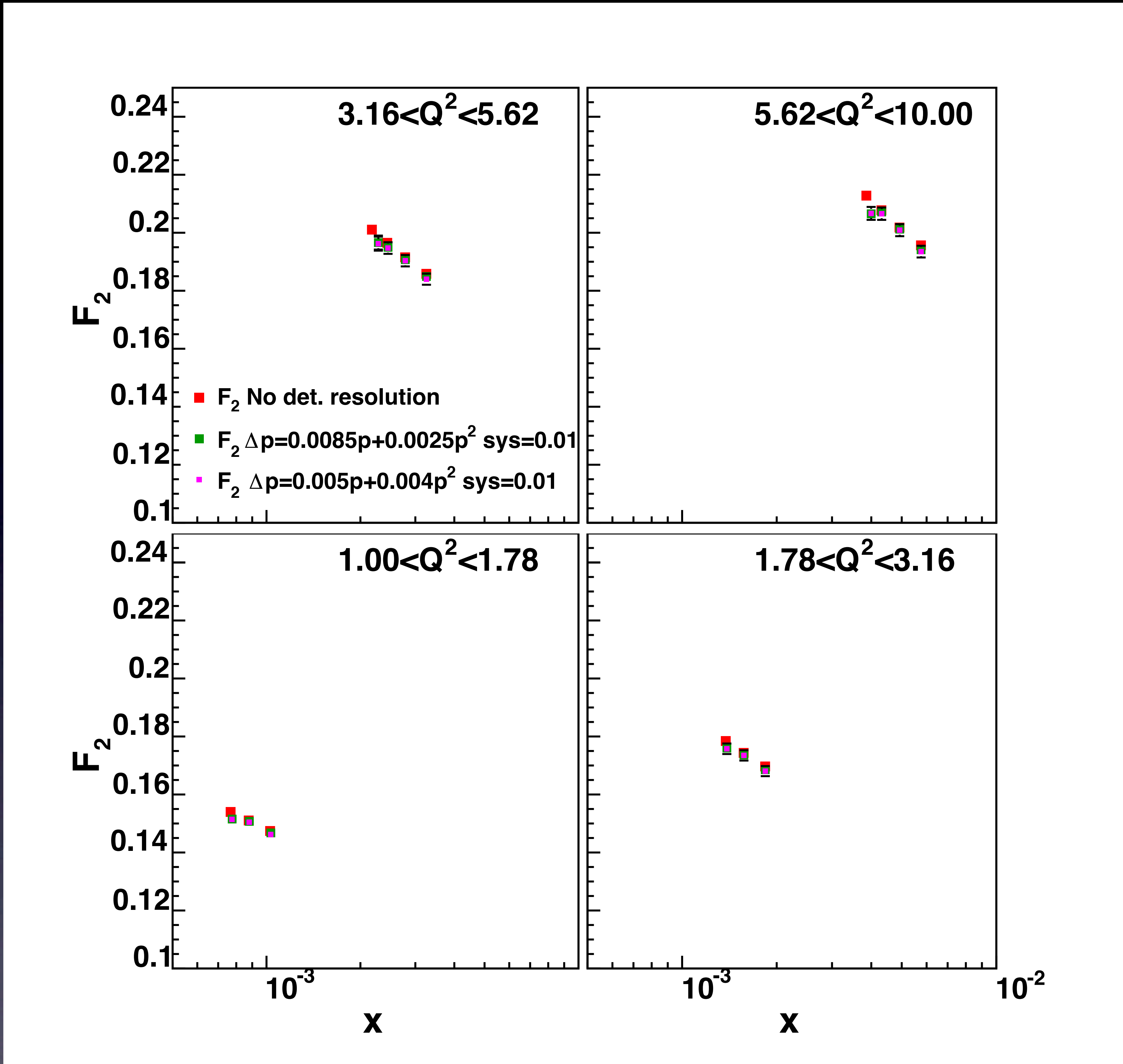
F_L extracted at four low values of Q^2.

The red markers show F_L extracted from a simulation with perfect detector resolution.

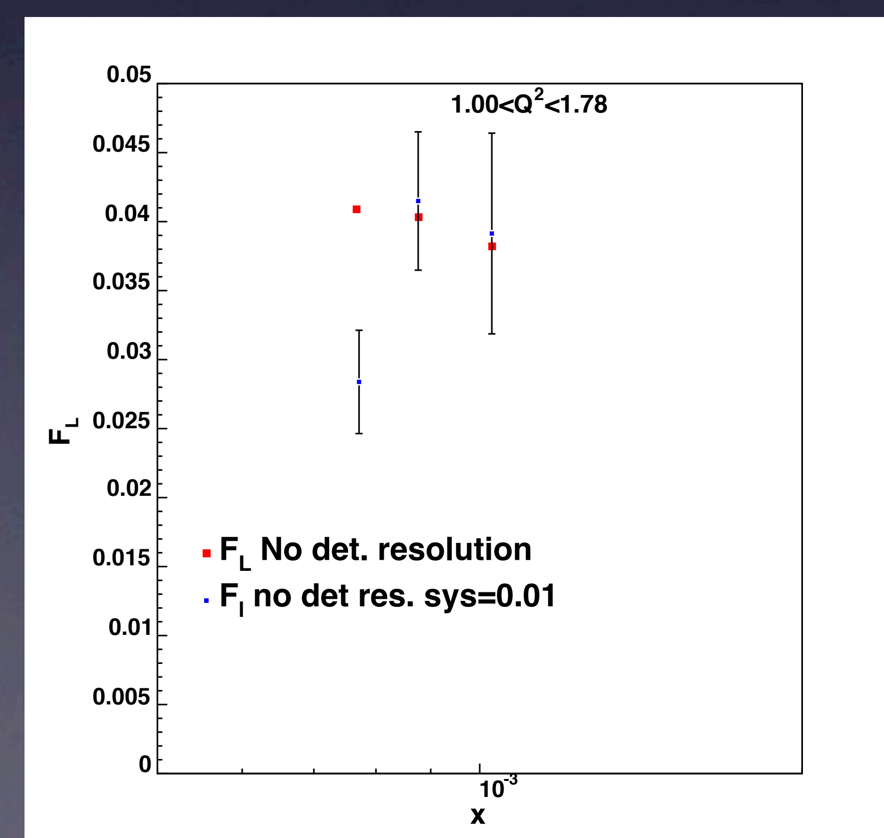
The blue markers correspond to a detector with good θ and p resolution.

The Magenta markers show the effects of poorer p resolution.

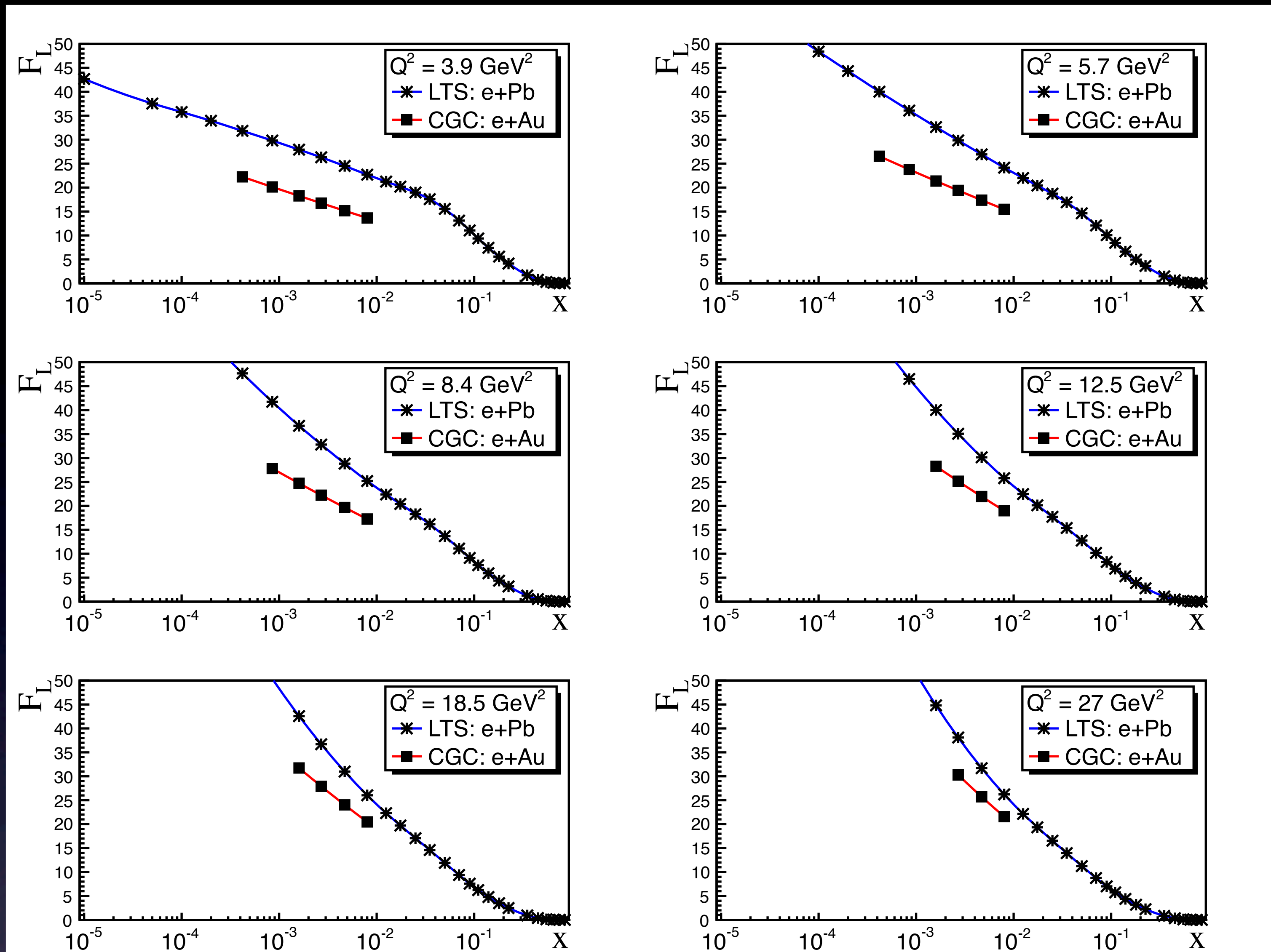
This shows how important it is to optimize the detector performance



The extraction of F_2 is less affected by detector resolution or other systematic uncertainties.



From our work with e+p LEPTO we learned that the measurement of small values of F_L is limited by systematic uncertainties.



Expected magnitude and x dependence of F_L at moderate values of Q^2.

The extraction of F_L from nuclear targets will not be dominated by systematic uncertainties.

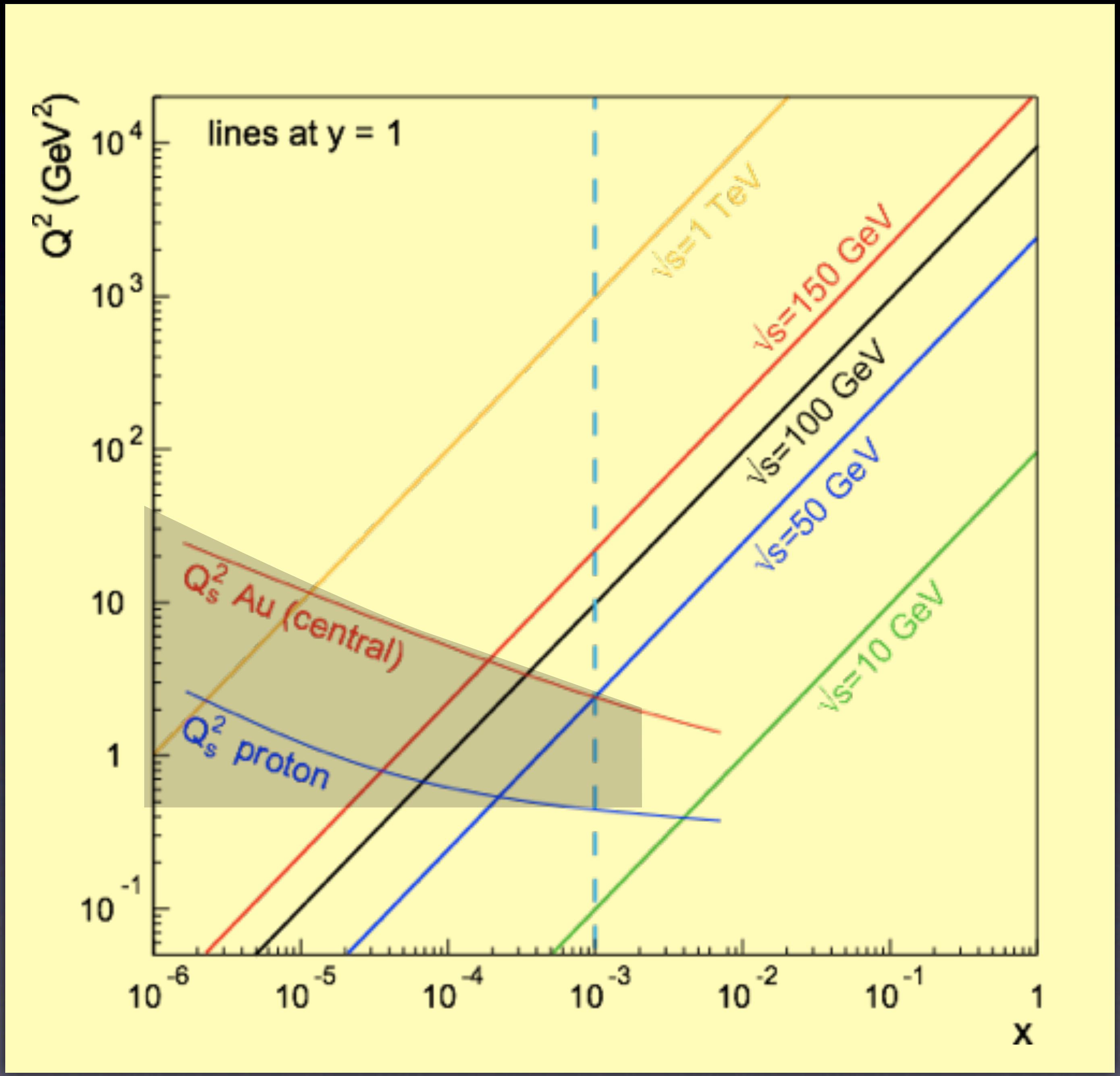
The blue curve displays the calculation at Leading Twist and the red one includes the presence of non-linear effect related to the Color Glass Condensate regime.

Summary and outlook

We have investigated the effects of detector resolution on the extraction of F_2 and F_L.
As long as the value of F_L is small, this measurements are very sensitive to errors on the extraction of the reduced cross section and or systematic uncertainties.
This work continues with events generated for e+A collisions (nuclear PDFs) and will include the effects of radiative corrections.

Backup

$$Q_s^2(x,A) \sim cQ_0^2\left(\frac{A}{X}\right)^{1/3}$$



What is eRHIC

Electron accelerator

to be build

Unpolarized and polarized leptons 5-20 (30) GeV

e^-

e^-

e^+

70% e^- beam polarization goal

polarized positrons?

RHIC

Existing = $2B

p

Polarized protons 50-250 GeV

Light ions (d,Si,Cu)
Heavy ions (Au,U)
50-100 GeV/u

Polarized light ions He^3
166 GeV/u

Center mass energy range: $\sqrt{s}$=30-173 GeV;
Luminosity~100-1000xHera ranging from
e+p: 0.39 10^{33} (5X50) to 1.9 10^{33} (30X250)
e+A: 0.1 10^{33} (30X50) to 11.4 10^{33} (10X100)

Planned beam energies and luminosities

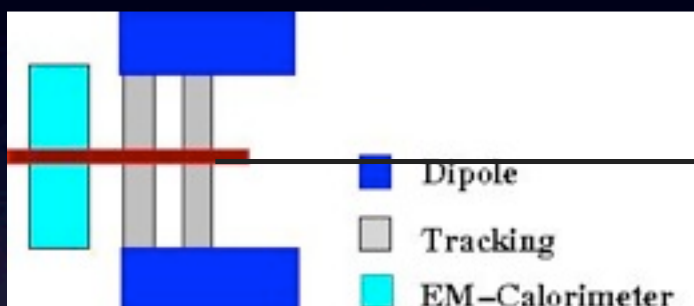
sqrt(s)	31.6	38.7	44.7	51.	70.7	44.7	54.8	63.2	72.1	100.
Beam Energies	5x50	5x75	5x100	5x130	5x250	10x50	10x75	10x100	10x130	10x250
ep	0.39e+33	1.3e+33	3.1e+33	5.0e+33	9.7e+33	0.39e+33	1.3e+33	3.1e+33	5.e+33	9.7e+33
eA	2.5e+33	8.3e+33	11.4e+33	18.0e+33		2.5e+33	8.3e+33	11.4e+33	18.0e+33	

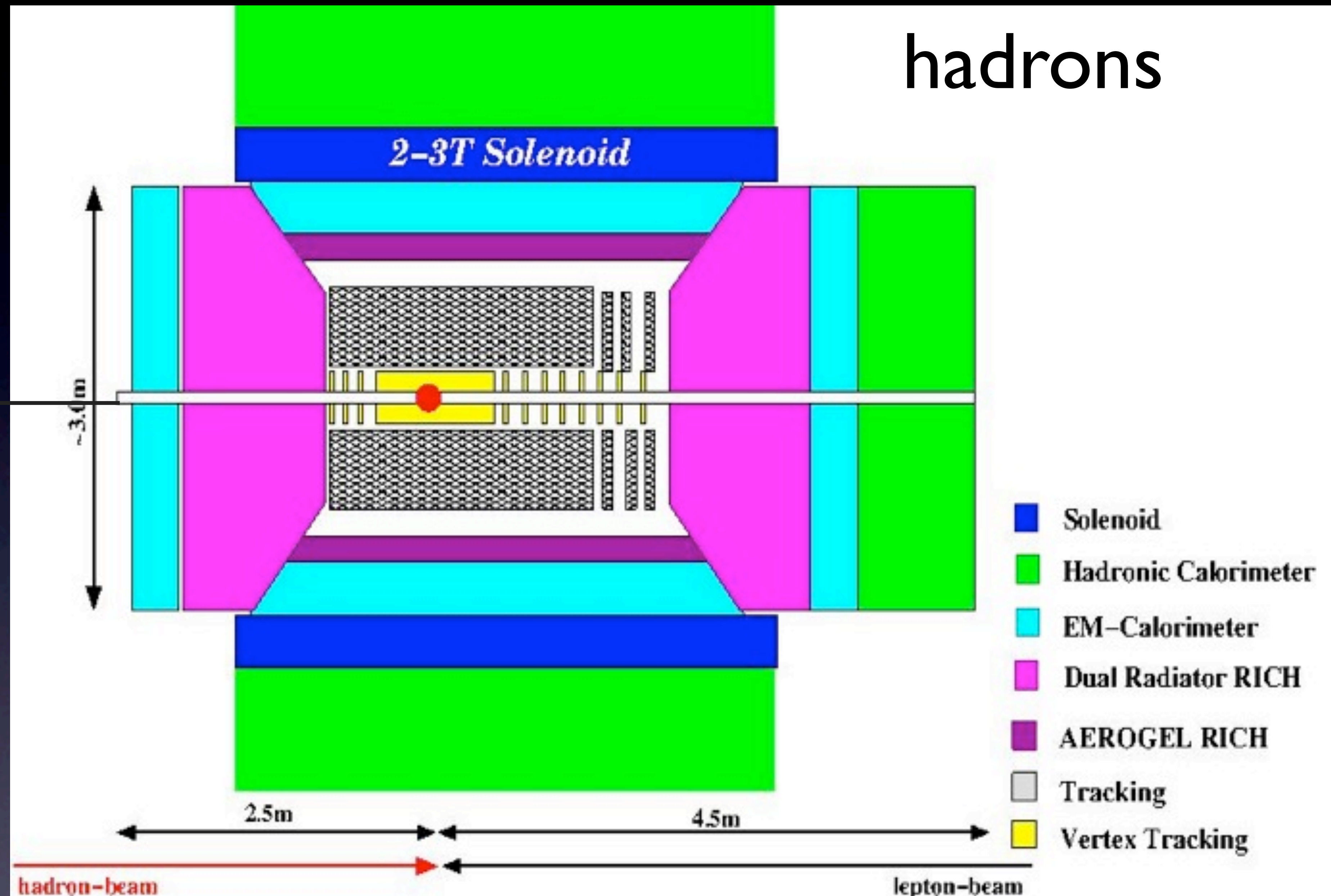
sqrt(s)	63.2	77.5	89.4	101.9	141.4	77.5	94.9	109.5	124.9	173.1
Beam Energies	20x50	20x75	20x100	20x130	20x250	30x50	30x75	30x100	30x130	30x250
ep	0.077e+33	0.26e+33	0.62e+33	1.4e+33	9.7e+33	0.015e+33	0.05e+33	0.12e+33	0.28e+33	1.9e+33
eA	0.49e+33	1.7e+33	3.9e+33	8.6e+33		0.1e+33	0.34e+33	0.77e+33	1.7e+33	

Proton beam energies can reach 250 GeV, nuclei (as Au) are limited to 100 GeV

The eRHIC detector

electrons





At low values of Q^2 the highest sensitivity for F_L extraction is found at high y and requires the detection of small electron scattering angles.

high acceptance $-5 < \eta < 5$ central detector
good PID (π,K,p and lepton) and vertex resolution (< 5μm)
tracking and calorimeter coverage the same → good momentum resolution, lepton PID
low material density → minimal multiple scattering and brems-strahlung
very forward electron and proton/neutron detection → maybe dipole spectrometers